THE GRINDING OF HARDWOODS

August 1942

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin

THE GRINDING OF HARDWOODS

Studies on Swamp Tupelo, Paper Birch, Green Ash, Sugarberry, Southern Cottonwood, Black Willow, and American Elm

By

E. R. SCHAFER, Senior Engineer
and
J. C. PEW, Associate Engineer

Summary

Investigations of the grinding of hardwoods have been conducted at the Forest Products Laboratory over a period of years with results that should be of interest to manufacturers of papers containing groundwood, who now obtain suitable softwood species at considerable distances from their mills. Hardwoods, by their ready accessibility to many groundwood mills, offer distinct advantages from the standpoint of pulpwood transportation costs. Increased use of hardwoods would also aid in the improvement of mixed stands of hardwoods and coniferous woods, and would expand our pulpwood resources.

Swamp tupelo, if ground soon after cutting, yields a groundwood pulp that is light colored and short fibered. It lacks the strength considered essential in the pulps produced from spruce and other softwoods but, even so, can be used in appreciable quantities as filler stock in the manufacture of book, magazine, and newsprint paper. Groundwood pulp made from paper birch has similar properties. The absorbent quality of this pulp was demonstrated in the production of a highly absorbent toweling paper. The pulps made from green ash and sugarberry were stronger than those made from tupelo and birch, but not so strong as standard pulp made from spruce. Satisfactory newsprint papers were made, however, in which both species constituted a considerable part of the furnish. The groundwood pulps obtained from southern cottonwood and black willow were comparable in strength with commercial groundwood. Although the color of the latter is too dark to permit its use in newsprint or other light colored papers, it should be suitable for papers and boards in which the dark color is not objectionable. Groundwood pulp made from American elm was both short fibered and dark colored, qualities which limit its use to such products as filler stock for boards and papers of low color.

The energy consumed in the making of groundwood pulps from hardwoods need not be so high as is generally believed necessary. For many purposes a satisfactory groundwood can be made from these woods with less energy than is ordinarily consumed in the grinding of softwoods. Some hardwoods, moreover, yield more pulp per cord than can be obtained from the softwoods.

Introduction

Although spruce still is fairly plentiful in some sections of the United States and Canada, groundwood mills in some regions of this country have been compelled to transport wood from distant points. Thus, the increased cost of the wood offsets to a great extent the cheapness of the process. The spruces are the most desirable species from which to make groundwood pulp, with the true firs, western hemlock, and southern pine following in order. The idea of employing hardwoods in this process is not new, and certain of the hardwood species have been used to a limited extent for a number of years. In fact, aspen was one of the first species used in the groundwood process. Increased use of hardwood species is worthy of consideration not only as a wartime measure to employ a cheap and abundant material resource, but also as good forestry practice resulting in lasting future benefits. For instance, increased utilization of hardwoods in the Southern States would be conducive to improved forest stands throughout that area.

The grinding of hardwoods has been attempted many times, but the amount of published technical information on the subject is relatively small. Thickens and McNaughton (8) studied the grinding of aspen, paper birch, and black tupelo and noted that relatively dull stone surfaces and higher energy consumption were required to produce pulp comparable with spruce groundwood. Running (6) reported that strength approximating only one-half to two-thirds that of spruce is obtained from aspen ground under the same conditions. Cottonwood and poplar require more power and the pulps have lower freeness for given bursting strengths than some of the coniferous species, according to experiments conducted by Wynn-Roberts (9). Munro (5) suggests that the use of a 9- or 10-cut, high-lead burr, or even a thread burr, is better for the grinding of aspen than a 12 or 14 straight or diamond burr. A moderate pressure and low temperature are also desirable. Benninger (1) found that beech was more easily ground than spruce. The foaming of the beech groundwood was, however, quite troublesome. He also reported that a 50-50 mixture of beech and spruce groundwood pulps was satisfactorily used. Other foreign investigators (2, 3) have published results similar to those of the American observers. Boiling or steaming the hardwood before grinding aids in improving strength, increasing fiber length, and lowering energy consumption per ton, but produces a brown pulp (4, 8).

Since the early work of Thickens and McNaughton, the Forest Products Laboratory has conducted various experiments in the grinding of several hardwoods. This report summarizes the results of these researches.

Swamp Tupelo

Table 1 contains data for the grinding of swamp tupelo (Nyssa biflora) (formerly swamp black gum), an abundant species in the southern United States. It ranges from Maryland to Florida and westward to eastern Texas. The samples tested were obtained from North Carolina. The wood was ground as

received and again after treatment with sodium sulfite solutions. In all experiments on untreated wood, the pulps obtained were low in strength and average fiber length as compared to standard spruce groundwood. The pulps obtained by grinding on a dull-surfaced stone and with high pressure were more completely fibrillated and slightly stronger than those obtained with the use of sharper stone surfaces.

These swamp tupelo groundwood pulps had an excellent color. The color of groundwood pulps obtained in other experiments was found, however, to be influenced greatly by the conditions of storage prevailing prior to pulping of the wood. It has been pointed out in a previous publication (7) that the light-colored sapwood in the freshly cut wood became discolored in less than 2 months if stored in a warm, moist condition, such as might prevail in southern climates during the summer. The fresh wood did not discolor if dried rapidly, indicating that moisture was an essential factor in the discoloration. Pulping the wood soon after cutting, before discoloration can occur, would appear to be a desirable practice.

The wood was chemically treated before grinding to improve the strength and increase the average fiber length of the pulp. Most pretreating processes, however, discolor the wood, and this discoloration, of course, prevents the use of the groundwood pulp in light-colored papers. Since the neutral sulfite solutions used in the semichemical process of treating chips do not discolor the wood if properly applied, the liquor used in these experiments was of that type, i.e., a mixture of sodium sulfite and sodium bicarbonate. Log sections about 28 inches long were weighted down in a treating cylinder and covered with the chemical solution. The conditions of the various treatments are summarized in table 2.

When the temperature of treatment was in the range of 150° to 170° C., the wood was discolored and the brownish groundwood pulps were obtained. When alternating vacuum and pressure were used, with the temperature during the pressure period not exceeding 130° C., the pulps obtained from the treated wood were not discolored. When wood treated by the latter method was ground on a dull stone with moderate pressure, the pulps had fair strength and were longer fibered than the untreated wood pulps.

Papermaking experiments indicated that the tupelo groundwood pulps made from untreated wood were more useful as filler stock than to provide strength. Data for newsprint and book papers are given in table 3. In most of the newsprint experiments in which 70 to 75 percent of groundwood and 30 to 25 percent of sulfite pulp were used, the strengths were below standard for this grade of paper. One, however, (machine run 447) in which 70 percent of tupelo groundwood was combined with 30 percent of commercial spruce sulfite pulp, was of slightly higher weight, but otherwise equal to standard newsprint. Another experiment in which 50 percent of the furnish consisted of tupelo groundwood, 20 percent of slash pine groundwood, and the remainder spruce sulfite pulp, (machine run 350) had normal strength. A run in which the tupelo groundwood content was reduced to 50 percent and the slash pine sulfite component was increased to 50 percent (machine run 443) had higher than standard newsprint strength. Although no trials were made in which hardwood and coniferous groundwood pulps were combined with either hardwood

neutral sulfite semichemical or pine semibleached sulfate pulps, the applicability of swamp tupelo groundwood in such furnishes is suggested by the results of experiments, to be discussed later, in which a paper birch groundwood of similar type was so used.

Acceptable sheets of book paper were made, in which the normal component of soda pulp was substituted in whole or in part with tupelo groundwood (machine runs 339, 441, and 442). These papers possessed good color, finish, and strength. One of the papers in this group (run 340) was, except for its low bursting strength, typical of rotogravure paper in its properties.

The papers having treated tupelo groundwood as part of their furnish were rough of surface and weak. Further study of pulps of this type is necessary to learn more about their papermaking characteristics.

Paper Birch

Paper birch (Betula papyrifera) is an important northern hardwood. It ranges from Labrador to Hudson Bay, southward to Long Island and northern Pennsylvania, and westward through Ontario, Michigan, and northern Wisconsin to western Minnesota and eastern Manitoba. The wood used in the experiments reported here was obtained from northern Wisconsin and Michigan. The grinding data are given in table 4.

The pulps produced were, in general, like those from the swamp tupelo; short fibered and low in strength, but, in spite of their short-fibered characteristics, quite free. Increasing the pressure of the wood on the stone surface from 20 pounds per square inch to 30 pounds and then to 40 pounds, successively, reduced both the strength and the unit energy consumption. Freeness was increased, but there was little change in fiber length. Contrary to experience with softwoods, raising the pit temperature (without change in consistency) produced a negligible effect.

Although the birch wood, especially when green, is quite white, the pulps were inclined to have a more or less pronounced orange tint. The coloring matter appeared to be water-soluble, but showed a tendency to become adsorbed on the pulp to some extent when standing in suspension. A sample of the pulp washed immediately after discharge from the grinder was decidedly improved in color.

The properties of the birch groundwood described above did not bar its use in several types of paper. Table 5 shows data for newsprint paper. When combined with birch neutral sulfite semichemical pulp and a coniferous groundwood pulp, birch groundwood may be used in proportions up to 30 percent of the total furnish with satisfactory results. The 50 percent of birch semichemical pulp used with this amount of birch groundwood brought the total hardwood content of the sheet to 80 percent. Comparing the properties of the experimental papers with the averages for commercial newsprint papers, it is noted that nearly all of the experimental papers are equal to or better than the commercial standard in most properties.

Certain grades of toweling paper contain from 40 to 50 percent of groundwood pulp, usually made from spruce and balsam, the remainder of the furnish being spruce sulfite pulp. The short fiber, softness, and apparent absorbent qualities of birch groundwood suggested its possible use in this grade of paper. The principal data obtained in several experiments in the making of toweling paper are given in table 6. The birch groundwood was substituted for part or all of the spruce groundwood in amounts varying from 15 to 45 percent of the total furnish. The birch groundwood lowered the strength slightly, but this was overcome to some extent by a little beating or jordaning. The drainage from the wire was slower and the wet strength of the web before passing the creping doctor was lowered. Considerable picking occurred on the dryers. In commercial operation, these machine-operating characteristics will need to be controlled by appropriate countermeasures. The water-absorption rate of the toweling paper was greatly increased by the addition of the birch pulp. One of the best papers, meeting most of the strength requirements of the standard toweling paper, contained 25 percent of birch groundwood (machine run 1707). This paper had more than 3 times the absorbency of the standard.

Green Ash, Sugarberry, and Southern Cottonwood

Green ash, sugarberry, and cottonwood were received and tested at the same time. For this reason, it is convenient to consider them as a group. Green ash (Fraxinus, pennsylvania lanceolata) is widely spread throughout southern Canada and the United States as far west as the eastern ranges of the Rocky Mountains. Sugarberry (Celtis laevigata), also commonly known as hackberry, is a bottomland hardwood growing in the southern United States, being quite plentiful in the Mississippi valley. Southern cottonwood (Populus deltoides virginiana) occurs in river valleys throughout the eastern, southern, and central United States. The woods used in this study were received from the delta region of Arkansas.

The grinding data are given in table 7, which includes for comparison purposes data on paper birch and southern pine and average values for commercial newsprint groundwood pulps.

By lowering the grinding pressure on the sugarberry from 30 to 20 pounds per square inch of wood on the stone surface the pulp strength was raised a little but a large increase in energy consumption per ton was attained. When the pressure was raised to 40 pounds, on the other hand, very little lowering of strength was produced and both a marked increase in production and a lowering of energy consumption were achieved. The response with ash was similar to that with sugarberry, except that the increase in pressure reduced the unit energy consumption only slightly.

Comparing the groundwood pulps produced at 30 pounds per square inch, it is apparent that the unit energy consumptions for these three hardwoods are in the range of commercial practice for newsprint groundwood, with that from sugarberry being somewhat high. The fibers of the sugarberry and ash were much shorter (as indicated by the screen analysis) than average fibers of

the commercial groundwoods and slightly shorter than those of birch pulp. The cottonwood was low in the coarsest mesh fraction (24-mesh), but otherwise approached commercial pulps in screen analysis. The sugarberry and ash had only fair bursting and tensile strengths and poor tearing strength. The cottonwood equaled the commercial average in bursting and tensile strength, but was somewhat lower in tearing strength. The sugarberry, ash, and cottonwood were all superior in strength to the birch groundwood although none was as strong as the southern pine groundwood. All of them were comparable with spruce groundwood in color.

These hardwood groundwood pulps were used in newsprint papermaking experiments with southern pine groundwood pulp and semibleached southern pine sulfate pulp. The data are given in table 8. On the basis of machine runs 1770 and 1771, it was found that a furnish containing 20 percent of cottonwood groundwood, 60 percent of pine groundwood, and 20 percent of pine sulfate, lightly jordaned, gave a paper about equal to the average commercial newsprint. The whiteness, at 65 percent, was very good. When the cottonwood groundwood content was increased to 40 percent (machine run 1772) and the same total groundwood content was maintained, the tensile strength was lowered about one-fifth, but there was practically no change in bursting strength. The tearing strength was higher than the standard average.

The relative effect of the three hardwood species may be noted by comparing machine runs 1772, 1773, and 1775. The paper of run 1772, containing cottonwood groundwood, was about equal in quality to that of run 1773, which contained an equal amount of ash groundwood, while the paper from run 1775, containing sugarberry groundwood, was poorer. Machine run 1777 was made with a furnish consisting of equal amounts of the three hardwood groundwoods, 39 percent in all. The rest of the furnish was pine groundwood and semibleached sulfate in about the proportions used in the three runs just discussed. With the exception of tearing resistance, the test values for all strength properties are less than the average for commercial newsprint. In these newsprint experiments it appeared that at least 20 percent of semibleached sulfate pulp was required to bring the bursting and tensile strengths up to values comparable with commercial newsprint. This amount of sulfate pulp produced a tearing strength higher than the standard. Although none of the hardwood-containing papers were quite as strong as the average for pine groundwood and sulfate alone, they are considered satisfactory for use as newsprint paper.

Summarizing these experiments, it is indicated that groundwood pulp of acceptable quality can be made from cottonwood, green ash, and sugarberry. In the making of newsprint paper, these pulps can be combined, in quantities as high as 40 percent, with southern pine groundwood and semibleached sulfate pulps to produce a satisfactory furnish.

Black Willow and American Elm

Black willow (Salix nigra) occurs in bottomlands throughout the northeastern, eastern, central, and southern United States except in Florida and the southeastern parts of South Carolina, Georgia, and Alabama. American elm (Ulmus americana) ranges from southern Canada south to central Florida and west

through the Central States to the foothills of the Rocky Mountains. The samples tested at the Laboratory were received from the Arkansas delta region, as were the three hardwoods discussed in the foregoing section. The data are given in table 7.

The black willow groundwood, like the cottonwood, was low in the 24-mesh screen fraction, but was about equal to the commercial groundwoods in strength. The elm groundwood was more like the sugarberry in fiber length and strength. Under comparable grinding conditions, the energy consumption for the elm was higher than that for the willow, which was normal for groundwood of newsprint grade. The dark color of these pulps was their principal defect, and it was for this reason that papermaking tests were not made with them. It is entirely possible that willow and elm groundwood pulps can be used in papers and boards in which color is not so important, as, for instance, in insulating board or container board filler, but no experiments were made to ascertain this.

General Considerations

It is generally believed that the production of groundwood pulp from hardwoods requires a high expenditure of energy. This is often true when it is sought to produce pulp comparable to spruce groundwood in strength and fiber length. In fact, it is doubtful whether these properties can be obtained with such dense, short-fibered hardwoods as tupelo, birch, beech, maple, sugarberry, and ash. There are uses for groundwood pulp, however, in which the strength and fiber length normally obtained from spruce are not necessarily required. The data in tables 1, 4, and 7, give evidence that pulps satisfactory for certain purposes can be made from this class of hardwoods with average or below average energy consumption. Hardwoods of lower density such as cottonwood, aspen, willow, etc., yield relatively free groundwoods with average strength and normal energy consumption. The fiber length of these groundwoods is, as a rule, somewhat less than that of spruce, and the color of some of them limits their field of usefulness.

Because of the short fiber of some hardwood groundwood pulps, considerable difficulty is experienced in attempting to form laps on the wet machine in the customary manner. It might be better, in such instances, to take the pulp off the machine in loose, crumbled form and store it in bales instead of laps. Better still, perhaps, would be the use of a slush system entirely when grinding hardwoods. Close attention must also be paid to the prevention of white water fiber losses when operating with hardwood groundwood pulps, by providing a properly closed system and adequate save-alls. Some mill operators have abandoned the grinding of hardwoods, for the reason that low yields were obtained. A modification of the wet machine operation and white water system might have been a solution to these difficulties.

Some of the hardwoods have fairly high densities in contrast to the softwoods usually used for groundwood manufacture. The resultant higher weight of wood per cord, and the consequent higher weight yield of pulp are factors to be considered in their favor. For instance, the hardwoods studied, with the

exception of cottonwood and willow, ranged from about 2400 to 2700 pounds of moisture-free wood per standard cord. The cottonwood and willow were comparable with spruce in weight per cord, namely around 2000 pounds. In these days of uncertain transportation, it might be advantageous to procure hardwoods, even at a higher price per cord, in stands close to the mill than to purchase softwoods at a lower price, but requiring a longer haul.

Literature Cited

(1) Benninger, Fritz.
Groundwood from beech. Wochbl. Papier fabr. 72:118-120 (1941).

(2) Brecht, W.; Schrotter, H.: Suttinger, R.
A comparison of various woods in mechanical pulp manufacture. Papier fabr. (Tech. Wiss Teil) 36 413-420 (1938).

(3) Briefkasten.
Groundwood from aspen. Wochbl. Papier fabr. 68 (33):622; (35):655; (36):681; (Aug. 14, 28, Sept. 4, 1937).

(4) Kin, Myron; Libby, C. E.
The manufacture of brown mechanical pulps from hardwoods. I yellow birch. Paper Ind. and Paper World 22 (7):675 (Oct. 1940); (9):918-923 (Dec. 1940); (10):1043-1048 (Jan. 1941).

(5) Munro, W. A.
Poplar wood as a substitute in the manufacture of groundwood. Paper Trade Jour. 77 (20):60 (Nov. 15, 1923).

(6) Running, K. D.
Hardwood utilization by the paper industry. Pulp and Paper Mag. Can. 42 (2) 104-106 (Convention issue 1941).

(7) Schafer, E. R.; Pew, J. C.; Pillow, M. Y.
Discoloration of swamp black gum pulpwood in storage. Tech. Assoc. Papers 22:405-8 (1939).

(8) Thickens, J. H. and McNaughton, G. C.
Groundwood pulp. U. S. Dept. Agric. Bull. 343 (April 26, 1916).

(9) Wynn-Roberts, R. I.
Grinding characteristics of various woods. Paper Trade Jour. 104 (6) 46-48 (Feb. 11, 1937).

Table 1.--Grinding of untreated and treated swamp tupelo

Grinder run No.	Wood No.	Surface of stone[1]: Type of burring[2]	Surface of stone[1]: Sharpness	Pressure of wood on stone[3]	Average temperature of stock in pit	Screened pulp per 100 pounds of wood[4]	Screenings per 100 pounds wood	Dry wood ground[5]	Energy requirement[6]: Input to grinder	Energy requirement[6]: Per ton dry wood	Freeness 0.4 percent at 20° C. (Green)	Screen analysis: Retained on 24 mesh	Screen analysis: Retained between 24 and 32 mesh	Screen analysis: Retained between 32 and 42 mesh	Screen analysis: Retained between 42 and 60 mesh	Screen analysis: Passing 60 mesh	Screen analysis: Coarseness modulus	Properties of test sheets[7]: Bursting per pound per ream 25 x 40 - 500	Properties of test sheets[7]: Tearing per pound per ream 25 x 40 - 500	Properties of test sheets[7]: Tensile breaking length	Properties of test sheets[7]: Stretch	Cleanliness	Color of pulp: White	Color of pulp: Primary tint	Color of pulp: Secondary tint
				Lb. per sq. in.	°F.	Pounds	Pounds	Tons	Hp.	Hp. - days	c.c.	Percent	Percent	Percent	Percent	Percent		Pt. per lb. rm.	Gm. per lb. rm.	Meters	Percent	Dirt particles per sq. in.	Percent	Percent	Percent
Untreated wood																									
8		A-120, B	Medium	10.9	130	68.3	0.9	0.80	21	51	50	0	0.3	0.7	2.1	96.9	0.04	0.01	0.09	142	0.50	3.5	69	6.8 yellow	3.2 orange
9		B-130, A	Medium	16.3	135	78.0	1.4	1.09	28	51	40	0.2	1.0	3.3	7.9	87.6	.18	.09	.16	239	.50	10.5	73	5.1 orange	0.9 yellow
10		B, A	Sharp	21.7	130	73.5	1.7	1.79	28	31	53	.8	2.2	5.9	6.9	84.2	.28	.02	.16	238	1.50	7.4	69	......do...	......Do
14		A-130, B-130	Sharp	17.2	115	82.4	.4	2.24	26	23	83	.2	.7	1.3	2.5	95.3	.08	......	......	......	......	6.8	71	5.8 ..do...	1.4...Do
15		A-196, B-196	Medium	39.6	115	85.2	.5	3.86	41	21	118	.3	.9	3.6	5.9	88.5	.19	(10)	(10)	(10)	(10)	2.3	72	6.4...do...	...
25		E, F	Very dull	22.9	140	61.0	.4	.28	26	175	70	.1	.5	2.4	2.8	94.2	.09	.09	.28	1457	2.50	2.2	72	3.8...do...	0.2 red
26		E, 215, F-215	Very dull	40.0	155	80.3	.3	.72	36	97	22	.1	1.3	3.5	4.7	90.4	.16	.13	.32	1009	3.75	5.1	71	2.6. .do...	.4...Do
27		C	Very sharp	22.9	90	80.2	.6	2.42	26	21	70	.5	1.3	3.6	6.4	88.2	.19	0	.08	92	1.00	7.3	64	5.4 yellow	2.6 orange
28		C-31	Very sharp	34.4	95	85.2	.5	3.43	30	17	116	.2	.5	1.6	4.4	93.3	.10	0	.05	87	.87	4.8	67	3.8 orange	3.4 yellow
45		D-560, F-210	Dull	43.6	160	82.2	1.6	1.30	44	66	24	.2	.4	1.5	4.3	93.6	.09	.06	.17	1120	2.50	......	67	5.8...do...	2.3...Do
46		D	Sharp	22.9	125	89.4	.5	2.49	33	26	76	.1	.2	1.6	5.3	92.8	.10	(10)	(10)	(10)	(10)	......	62	7.0...do...	.5...Do
Commercial samples -- average of 29 newsprint grade ground wood pulps							......	......	......	65	83	16.7	6.9	7.0	7.7	61.7	1.13	.19	.59	1780	......	......	59	......	......
Treated wood[9]																									
18	2322B	A-125, B-125	Sharp	11.5	105	76.9	.9	.64	20	60	305	30.9	11.1	7.4	6.4	44.2	1.78	.12	.54	1037	.25	2.3	40	7.7...do...	0.2 red
19	..do..	A-360, B-360	...do......	22.9	100	84.3	1.0	1.28	25	37	325	27.6	8.6	6.6	6.1	51.1	1.56	.10	.48	1327	.37	1.7	41	9.0...do...	.4...Do
20	..do..	A-455, B-455	Medium	34.4	105	82.9	1.7	1.71	28	37	500	45.1	7.8	5.3	4.8	37.0	2.19	.08	.41	1086	.25	2.0	36	......do...	1.0...Do
21	2323B	A-525, B-525	...do......	22.9	95	82.4	1.3	2.34	28	24	423	24.3	9.7	7.0	6.7	52.3	1.47	.06	.30	759	2.75	1.3	41	7.7...do...	.6...Do
22	..do..	A-585, B-585	...do......	34.4	100	84.8	1.2	2.48	29	23	533	22.4	9.6	7.9	7.2	52.9	1.41	.03	.21	571	2.25	1.0	42	9.0...do...	.2...Do
23	2326B	A, B	Sharp	22.9	100	78.6	1.7	1.58	25	31	465	42.6	7.9	6.4	5.8	37.3	2.13	.15	.65	1410	3.00	1.8	35	7.7...do...	.6...Do
24	..do..	A-80, B-80	...do......	34.4	95	81.5	1.6	1.79	27	29	487	43.4	7.7	5.4	4.8	38.7	2.12	.14	.45	1800	3.00	1.0	33	7.7...do...	.. ...Do
31	2330B	C-237, D-182	...do......	22.9	85	89.3	.6	2.73	24	17	525	4.0	7.8	8.2	10.5	69.5	.66	0	.11	177	1.25	2.6	73	1.3...do...	1.0...Do
32	..do..	C-273, D-218	...do......	34.4	85	90.3	.8	3.80	31	16	512	4.1	7.5	9.3	10.9	68.2	.67	0	.11	191	1.75	1.0	69	3.2...do...	1.4...Do
42	2347B	D-442	Dull	22.9	140	86.0	.9	1.15	27	46	235	29.6	8.5	7.2	7.0	47.7	1.65	.12	.56	1203	2.75	1.5	64	5.1...do...	.9...Do
43	..do..	D-560, F	...do......	28.7	150	91.8	.6	1.48	37	48	85	13.3	8.4	7.6	8.2	62.6	1.02	.16	.54	1409	3.50	1.7	70	5.1...do...	.4...Do

[1] The two-pocket experimental grinder was equipped with an Opekiska sandstone 26 inches in diameter and 11 inches wide operated at a peripheral speed of 3300 feet per minute.

[2] Burrs used were as follows. A, four cut straight burr (i.e., four teeth per inch); B, 10 cut spiral burr, 1-1/4-inch lead; C, 14 point diamond burr; D, eight cut spiral burr, 1-1/4-inch lead, E, worn 10 point diamond burr. F, a brick used to dull stone surface. The number following the burr letter indicates the minutes the stone was in service from the time the burr was applied to the beginning of the run in question. Burrs were used in the order indicated.

[3] Calculation based on total thrust on pressure foot divided by the area represented by the product of the width of grinder pocket and length of the wood.

[4] Figures low due to accidental loss of pulp at the wet machine. There was also considerable loss in the white water.

[5] Per square foot of wood-stone contact area per 24 hours.

[6] Corrected for motor efficiency (91 percent) and efficiency in the belt transmission (97 percent).

[7] Strength tests were made at 65 percent relative humidity and 72° F.

[8] Measured by Ives photometer.

[9] See table 3 for conditions of treatment.

[10] Too weak to form test sheets of customary weight of 115 pounds per ream.

Z M 42512 F

Table 2.--Chemical treatment of swamp tupelo before grinding

Digestion No.	Wood used in grinder run Nos.	Wood: Length of bolts	Wood: Average diameter	Wood: Amount of oven-dry wood: In wood taken	Wood: Amount of oven-dry wood: In treated wood	Treating liquor: Fresh: Volume	Treating liquor: Fresh: Concentration: Na_2SO_3	Treating liquor: Fresh: Concentration: Na_2CO_3 (1)	Treating liquor: Blow back: Volume	Treating liquor: Blow back: Concentration: Na_2SO_3	Treating liquor: Blow back: Concentration: Na_2CO_3 (1)	Treating liquor: Spent: Volume	Treating liquor: Spent: Concentration: Na_2SO_3	Treating liquor: Spent: Concentration: Na_2CO_3 (1)	Chemical absorbed: Na_2SO_3	Chemical absorbed: Na_2CO_3 (1)	Impregnation: Duration	Impregnation: Maximum temperature	Impregnation: Average pressure	Cooking: Duration	Cooking: Maximum temperature	Cooking: Average pressure	Alternate pressure-vacuum treatment: Duration of cycles[2]: Vacuum phase	Alternate pressure-vacuum treatment: Duration of cycles[2]: Pressure phase	Alternate pressure-vacuum treatment: Maximum vacuum	Alternate pressure-vacuum treatment: Maximum pressure	Range of temperature: Cycle 1	Range of temperature: Cycle 2	Range of temperature: Cycle 3	Range of temperature: Cycle 4	Range of temperature: Cycle 5
		Inches	Inches	Per-cent	Per-cent	Gal. per 100 lbs. O.D. wood	Gm. per L	Gm. per L	Gal. per 100 lbs. O.D. wood	Gm. per L	Gm. per L	Gms. per 100 lbs. O.D. wood	Gm. per L	Gm. per L	Lb. per 100 lbs. O.D. wood	Lb. per 100 lbs. O.D. wood	Hours	°C.	Lb. per sq. in.	Hours	°C.	Lb. per sq. in.	Hours	Hours	Inches mercury	Lb. per sq. in.	°C.	°C.	°C.	°C.	°C.
2322N	18, 19, 20	9.0	7.1	65.9	49.0	25.0	75.3	14.8	35.8	47.4	8.2	......	2.2	0	1.63	0.63	2	108	145	1.5	170	125	......	......	......	......	......	......	......	......	......
2323N	21, 22	27.5	7.9	65.2	44.2	27.2	36.4	9.8	......	......	......	39.6	13.4	5.6	3.60	.36	1	102	145	3	170	130	......	......	......	......	......	......	......	......	......
2326N	23, 24	27.5	7.2	56.4	49.7	31.2	78.5	13.0	......	......	......	59.6	31.7	6.4	4.47	.21	3	95	145	6	150	72	......	......	......	......	......	......	......	......	......
2330N	31, 32	27.5	6.2	55.4	43.1	38.5	79.8	11.9	......	......	......	66.1	34.6	5.0	6.53	1.04	......	......	......	......	......	......	0.5	1.0	20	145	19-103	76-97	75-105	74-104	74-101
2347N	42, 43	27.5	......	73.3	44.8	33.0	91.9	15.4	......	......	......	39.3	54.2	9.6	7.33	1.05	......	......	......	......	......	......	0.5	.5	20	149	30-130	75-117	80-120	79-130	......

[1] Present as $NaHCO_3$ but calculated as Na_2CO_3.
[2] A "cycle" consisted of one vacuum and one pressure phase.

Table 3.--Book and newsprint papers containing swamp tupelo ground-wood pulp

Machine run No.	Furnish: Ground wood: Grinder run No.	Ground wood: Amount	Sulfite pulp: Species	Sulfite pulp: No.[1]	Sulfite pulp: Amount	Size	Alum[2]	Properties of the paper: Weight per ream 25 x 40 - 500	Thickness	Bursting[3] per pound per ream 25 x 40 - 500	Tearing[3] per pound per ream 25 x 40 - 500	Tensile, breaking length	Stretch	Whiteness	Castor oil penetration	Opacity	Gloss
		Percent			Percent	Percent	Percent	Pounds	Mils	Point	Gram	Meters	Percent	Percent	Seconds	Percent	Percent
Newsprint papers																	
350	9 [4]13	50 20	Spruce	3443	30	1.0	1.5	39	3.2	0.23	0.57	3080	0.95	63	49	93	34
346	10	70	Slash pine	3449	30	.5	1.3	38	3.3	.15	.42	2090	1.15	62	70	93	34
422	14	70	....do......	3457	30	.5	2.0	33	3.0	.14	.50	......	......	......	......	......	......
363	15	73	Spruce	3474	27	.5	1.5	38	4.4	.17	.48	1798	1.12	66	26	85	29
364	15	65	Slash pine	3456	35	3.0	4.5	36	4.0	.13	.61	1615	1.25	64	26	84	21
447	25	70	Spruce	P-946	30	.5	3.0	43	3.1	.26	.53	3123	1.50	73	147	93	38
443	26	50	Slash pine	3452	50	.5	3.0	35	3.0	.33	.57	......	......	62	......	......	......
476	26 [4]33	35 35	....do......	3485	30	.5	3.0	33	4.0	.20	.63	1835	1.15	67	27	86	26
465	27 [4]33	50 20	....do......	3485	30	.5	3.0	41	4.0	.13	.39	1205	1.15	68	11	83	29
463	28	50	....do..... Swamp tupelo	3485 3481	15 35	.5	3.0	36	4.3	.16	.48	1378	1.10	70	8	84	24
536	45	70	Slash pine	3506	30	.5	7.0	38	3.6	.18	.64	1369	1.40	61	26	97	35
481	[5]31	70	Spruce	P-946	30	.5	5.0	40	3.8	.10	.24	510	.75	73	5	87	35
459	[5]32	70	....do......	P-946	30	.5	3.0	39	4.0	.15	.41	1308	1.30	69	15	87	44
464	[5]32 [4]30	50 20	Slash pine	3485	30	.5	3.0	41	3.9	.13	.36	611	.50	70	10	81	30
530	42	70	....do......	3506	30	.5	7.0	38	3.5	.19	.69	2944	1.41	63	36	90	35
529	43	80	....do......	3506	20	.5	7.0	35	3.3	.15	.60	1890	1.19	62	22	90	31
Average of 56 commercial newsprint papers........................								38	3.3	.25	.54	2795	1.00	59	50	92	41
Book papers[6]																	
[7]340	8	60	Slash pine	3446	40	.5	2.5	56	5.4	.12	.42	1480	1.25	70	42	90	26
339	8	50	....do......	3446	50	1.5	3.0	36	4.5	.23	.72	2422	1.25	76	80	87	29
441	26	20	Spruce Hardwood[8]	P-927 P-925	60 20	1.5	3.0	57	3.3	.22	.78	2271	1.85	79	152	91	35
442	26	40	Spruce	P-927	60	1.5	3.0	54	4.5	.28	.65	2350	2.55	81	120	86	36

[1] "P" preceding the number of the pulp indicates a commercial product.

[2] To improve color, dye was added to the stock in the beater before adding alum.

[3] To convert the bursting and tearing strengths of the newsprint papers to the trade ream basis 24 x 36 - 500, multiply by 1.157.

[4] Slash pine ground-wood pulp.

[5] Wood treated before grinding.

[6] Furnish for machine runs 339 and 340 contained 15 percent of clay based on total fiber; runs 441 and 442, 25 percent of clay.

[7] A rotogravure type of paper.

[8] Commercial soda pulp.

ZM 42513 F

Table 4.--Grinding of paper birch

Grinder run No.	Average wood properties					Grinding data									Properties of pulp suspension								Properties of pulp test sheets						
	Diameter	Age	Rate of Growth	Density, dry weight per green volume	Dryness	Pressure of wood on stone[1]	Stone service[2]	Temperature of grinding	Consistency	Yield per 100 pounds dry wood: Screened pulp	Yield per 100 pounds dry wood: Screenings	Dry wood ground[3]	Power input	Energy consumed per ton dry wood	Freeness, Schopper-Riegler	Screen analysis: Retained on 24 mesh	Screen analysis: Retained between 24 and 42 mesh	Screen analysis: Retained between 42 and 80 mesh	Screen analysis: Retained between 80 and 150 mesh	Screen analysis: Passing 150 mesh	Fiber length index	Bursting per pound per ream 25x40 - 500	Tearing per pound per ream 25 x 40 - 500	Tensile per square inch	Solid fraction	Color analysis[4]: White	Color analysis[4]: Primary tint	Color analysis[4]: Secondary tint
	Inches	Years	Rings per inch	Lb. per cu. ft.	Percent	Lb. per sq. in.	Hours	°F.	Percent	Percent	Percent	Tons	Hp.	Hp. days	Cc.	Percent	Percent	Percent	Percent	Percent		Point	Gm.	Lb.		Percent	Percent	Percent
363	9.5	120.0	25.2	29.6	78.8	28.8	17.1	160	4.4	91.3	0.26	1.25	122	73	470	0.8	3.7	15.1	18.3	62.1	0.072	0.11	0.33	844	0.26	63	6.4-0	0
374	6.5	37.7	12.0	31.5	55.8	20.3	18.8	160	3.8	88.2	.27	.72	90	93	385	.1	1.3	11.8	20.8	66.0	.068	.09	.30	644	.27	70	5.1-0	0.9-Y
375	6.5	37.7	12.0	31.5	55.8	29.8	20.2	160	4.3	92.2	.43	1.39	124	67	475	.1	2.3	13.9	21.3	62.4	.069	.08	.25	528	.25	67	5.1-0	.6-R
376	6.5	37.7	12.0	31.5	55.8	40.3	20.8	160	4.3	96.1	.24	2.34	161	52	565	.2	2.4	14.3	21.0	62.1	.069	.06	.21	273	.23	63	6.4-0	.6-R
377	6.5	37.7	12.0	31.5	55.8	29.8	21.2	190	4.8	89.5	.37	1.31	117	67	510	.2	2.9	17.6	19.0	60.3	.070	.08	.26	480	.24	66	6.4-0	.2-R
378	5.8	36.6	12.8	31.8	56.5	40.0	22.0	160	4.6	94.1	.31	2.07	153	56	520	.2	2.4	16.5	23.8	57.2	.075	.07	.20	314	.23	61	7.0-0	.5-Y
Commercial pulp -- average of 29 newsprint grade pulps														65	....	17.0	14.0	(5)	....	....	....	.19	.59	945	......	59	....	....

[1]Actual thrust of the pressure foot (determined by calibration of the cylinder pressure) divided by the area represented by the product of the pocket width and the wood length.

[2]A Norton 3760/5-N7 stone was used. In previous service it had been burred with an 8-cut, 1-1/2-inch lead, spiral burr, and after 58.8 hours of use, lightly sharpened with a 14-point diamond burr. The hours given in this column were the service subsequent to this sharpening. The peripheral speed was 3150 feet per minute, and time of service was based on this speed and the equivalent of 3-pocket operation.

[3]Per square foot of wood-stone contact area per 24 hours.

[4]Color measured by the Ives photometer. The tint is designated as follows: O, orange; Y, yellow; R, red.

[5]Retained between 42 and 60 mesh, 8 percent, and passing 60 mesh, 61 percent.

Z M 42514 F

Table 5.--Newsprint papers containing birch ground wood and neutral sulfite semichemical pulps

Machine run No.	Birch pulp: Ground wood: Grinder run No.	Birch pulp: Ground wood: Amount	Birch pulp: Neutral sulfite semichemical: Cook No.	Birch pulp: Neutral sulfite semichemical: Amount	Coniferous ground wood: Species[1]	Coniferous ground wood: Amount	Properties of the paper: Weight per ream: 25 x 40 - 500	Thickness	Bursting[2] per pound per ream: 25 x 40 - 500	Tearing[2] per pound per ream 25 x 40 - 500	Tensile per square inch	Whiteness	Castor oil penetration	Porosity	Opacity
		Percent		Percent		Percent	Pounds	Mils	Point	Gram	Pounds	Percent	Seconds	Seconds	Percent
1659	377	18	3917-N	31	Jack pine	51	40	3.5	0.24	0.61	2940	63	73	57	90
1720	378	20	3920-N	60	Spruce	20	38	2.8	.35	.61	4450	53	43	49	88
1660	377	20	3917-N	35	Jack pine	45	39	3.5	.25	.57	2835	61	74	55	91
1647	363	21	3912-N	34	....do.....	45	37	3.1	.25	.44	3120	58	95	144	91
1727	378	20	3921-N	30	Spruce	50	40	3.2	.28	.59	2980	60	52	62	91
1728	378	20	3921-N	20	....do.....	60	38	3.3	.26	.49	2550	63	54	60	92
1721	378	30	3920-N	50	....do.....	20	39	3.0	.33	.54	3730	55	42	49	91
1724	378	30	3921-N	50	....do.....	20	39	2.8	.28	.58	3640	60	43	60	88
1725	378	30	3921-N	50	....do.....	20	38	3.1	.33	.60	3360	60	56	65	88
1723	378	30	3921-N	40	....do.....	30	38	3.0	.26	.49	2770	63	38	62	90
1722	378	40	3920-N	40	....do.....	20	41	3.6	.21	.47	1720	61	23	19	93
Average of 56 commercial newsprint papers							38	3.3	.25	.54	2537	59	50	52	92

[1]The Jack pine was from grinder run 361; the spruce was commercial ground wood.

[2]To convert to the newsprint trade ream basis 24 x 36 - 500, multiply by 1.157.

Z M 42713 F

Table 6.—Effect of birch ground-wood pulp in toweling paper

Machine run No.	Birch ground wood: Grinder run No.	Birch ground wood: Amount	Amount of spruce ground wood[1]	Unbleached spruce sulfite[1]: Amount	Unbleached spruce sulfite[1]: Beating	Jordaning	Calendering	Weight per ream 25x40-500	Thickness	Solid fraction	Burst	Tear	Tensile	Stretch	Absorption of water
		Per-cent	Per-cent	Per-cent				Pounds	Mils		Points per pound per ream	Grams per pound per ream	Pounds per square inch	Per-cent	Sec-onds
1702	......	None	45.0	55.0	None	None	None	39.5	10.52	0.14	0.21	1.09	525	4.65	263
1703	376	22.5	22.5	55.0	None	Jordaned	None	39.8	10.34	.14	.18	.85	502	4.80	58
1704	376	45.0	None	55.0	None	None	None	38.5	10.01	.14	.18	.85	416	5.50	37
1706	375	15.0	30.0	55.0	Beaten	None	None	37.4	10.76	.13	.19	.98	312	7.10	179
1707	375	25.0	20.0	55.0	Beaten	Jordaned	None	42.6	10.53	.15	.20	1.06	500	6.15	80
1708	375	25.0	20.0	55.0	None	Jordaned	Calendered	41.3	8.87	.17	.21	.87	659	5.75	125
1705	376	25.0	25.0	50.0	Beaten	None	None	41.7	10.56	.15	.14	.69	450	4.60	87

[1] Commercial pulp.

Table 7.--The grinding of southern cottonwood, sugarberry, green ash, black willow and American elm

Grinder run	Average properties of the wood					Grinding data									Properties of pulp suspension							Properties of pulp test sheets						
	Age	Rate of growth	Volume of heartwood	Density: dry weight: green volume	Dryness	Pressure of wood on stone[1]	Stone service time[2]	Consistency[3]	Yield per 100 pounds dry wood: Screened pulp	Yield per 100 pounds dry wood: Screenings	Dry wood ground[4]	Power input	Energy consumed per ton dry wood	Freeness Schopper-Riegler	Screen analysis: Retained on 24 mesh	Screen analysis: Retained between 24 and 42 mesh	Screen analysis: Retained between 42 and 80 mesh	Screen analysis: Retained between 80 and 150 mesh	Screen analysis: Passing 150 mesh	Fiber length index	Bursting per pound per ream 25 x 40 - 500	Tearing per pound per ream 25 x 40 - 500	Tensile per square inch	Solid fraction	Color analysis[5]: White	Color analysis[5]: Primary tint	Color analysis[5]: Secondary tint
No.	Years	Rings per inch	Per-cent	Pounds per cu. foot	Percent	Pounds per sq. inch	Hours	Percent	Pounds	Pound	Tons	Hp.	Hp.days	Co.	Percent	Per-cent	Per-cent	Per-cent	Per-cent		Point	Gram	Pound		Per-cent	Percent	Percent
Sugarberry																											
383	33.2	6.7	0	30.6	58.5	20	24.2	3.4	79.4	0.2	0.56	85	115	185	0.1	1.0	7.6	12.3	79.0	0.061	0.17	0.37	1122	0.25	68	3.8-O	0.9-Y
384	Do.	do.	do.	do.	do.	30	25.9	3.9	80.1	.3	1.11	123	83	273	.1	1.3	8.7	13.0	76.9	.062	.15	.35	958	.24	69	3.2-O	2.3-Y
385	Do.	do.	do.	do.	do.	40	26.8	4.2	83.5	.4	1.76	156	66	300	.2	2.3	9.9	15.6	72.0	.065	.15	.35	906	.23	65	3.8-O	.9-Y
Green ash																											
386	47.8	8.9	0	34.4	68.7	20	27.2	3.7	80.6	.1	.67	83	91	270	.1	.2	6.8	22.7	70.2	.065	.16	.31	914	.25	71	3.8-O	.4-R
387	Do.	do.	do.	do.	do.	30	28.9	4.9	83.5	.2	1.45	150	64	352	0	.2	7.3	20.7	71.8	.064	.13	.28	716	.24	72	3.8-O	.2-R
388	Do.	do.	do.	do.	do.	40	29.6	4.5	84.1	.3	1.81	149	62	317	0	.2	6.7	18.3	74.8	.063	.13	.26	790	.24	70	4.5-O	.5-Y
Southern cottonwood																											
389	26.0	4.1	41.8	23.6	42.9	30	30.2	3.7	93.8	.3	1.33	113	68	430	1.3	10.5	22.8	16.5	48.9	.084	.19	.45	1090	.25	64	5.1-O	1.8-Y
Black willow																											
390	28.0	3.8	36.1	23.6	42.2	30	31.0	4.4	94.1	.4	1.30	116	67	325	1.5	7.2	19.1	18.2	54.0	.079	.22	.50	1230	.25	44	7.7-O	0
American elm																											
391	55.2	8.1	22.8	29.5	47.3	30	32.0	4.3	87.9	.3	1.09	114	78	252	.1	2.7	11.0	13.4	72.8	.065	.16	.42	940	.25	52	9.0-O	.2-R
Included for comparison																											
Southern pine																											
392	13.1	3.8	0	29.3	45.4	32	32.8	4.0	92.5	.4	1.27	134	79	300	7.0	10.0	14.6	12.6	55.8	.080	.25	.59	1178	.25	66	6.4-O	2.7-Y
Paper birch																											
375	37.7	12.0	......	31.5	55.8	30	20.2	4.3	92.2	.4	1.39	124	67	475	.1	2.3	13.9	21.3	62.4	.069	.08	.25	528	.25	67	5.1-O	.6-R
Average of 17 commercial newsprint grade ground-wood pulps																											
......	......	......	......	......	......	......	......	......	......	......	......	......	65	......	17.0	14.0	(6)	......	......	......	.19	.59	945	......	59	......	......

[1] The actual thrust of the pressure foot (determined by calibration of the cylinder pressure) divided by the area represented by the product of the pocket width and the wood length.

[2] A Norton 3760/5-N7 stone was used. In previous service it had been burred with an 8-cut, 1-1/2 inch lead spiral burr and after 58.8 hours of use lightly sharpened with a 14-point diamond burr. The hours given in this column were the service subsequent to this sharpening. The peripheral speed of the stone was 3150 feet per minute. Although only two pockets of the grinder were in use at any one time, the time equivalent of wear of the stone surface is estimated on the basis of three-pocket operation at this peripheral speed.

[3] The temperature of grinding was 160° F.

[4] Per square foot of wood-stone contact area per 24 hours.

[5] Color measured by Ives photometer. The tint is designated as follows: O, orange, Y, yellow; R, red.

[6] Eight percent retained between 42 and 60 mesh and 61 percent passing 60 mesh.

Table 8.--Newsprint papers from southern cottonwood, green ash, sugarberry and pine

Machine run	Ground-wood pulp: Hardwood[1] Species	Ground-wood pulp: Hardwood[1] Amount	Ground-wood pulp: Southern pine[1] Amount	Semi-bleached sulfate[2]	Jordaning	Weight per ream 25 x 40 - 500	Thickness	Bursting[3] per pound per ream 25 x 40 - 500	Tearing[3] per pound per ream 25 x 40 - 500	Tensile per square inch	Whiteness	Castor oil penetration	Porosity	Opacity	Gloss
No.		Percent	Percent	Percent		Pounds	Mils	Point	Gram	Pounds	Percent	Seconds	Seconds	Percent	Percent
1770	Cottonwood	20	60	20	None	42	4.18	0.22	0.69	2,186	65	46	25	92	34
1771	Do.........	20	60	20	Light	38	3.60	.24	.57	2,549	65	56	55	91	36
1772	Do.........	40	40	20	...do..	37	4.45	.23	.66	2,020	65	43	29	91	33
1773	Green ash	40	40	20	...do..	40	3.85	.22	.64	2,151	67	35	27	94	35
1774	Do.........	40	45	15	None	43	4.21	.18	.57	1,852	66	30	20	95	35
1775	Sugarberry	40	40	20	...do..	41	4.06	.19	.61	1,801	67	33	19	93	34
1776	Do.........	40	45	15	...do..	40	4.26	.17	.70	1,685	66	36	21	93	34
1777	Cottonwood Green ash Sugarberry	13 13 13	41	20	...do..	39	4.07	.18	.70	1,805	65	32	21	93	34
Southern pine newsprint[4]			80	20	...do..	32	3.34	.29	.75	2,420	65	79	75	91	36
Average of 56 commercial newsprint papers...........						38	3.30	.25	.54	2,537	59	50	49	92	41

[1]

Species	Grinder run No.
Cottonwood	389
Green ash	388
Sugarberry	395
Southern pine	392

[2] In addition to the fiber furnish 0.25 percent of rosin size, dye, and alum to a pH of 4.5 to 5.0 was added. The semibleached pulp used was prepared from commercial southern pine kraft bleached to a whiteness of 56 as measured by the Ives photometer.

[3] To convert to the newsprint trade ream basis 24 x 36 - 500, multiply by 1.157.

[4] Average of machine runs 1088-1092 inclusive, 1148, 1149, 1152-1154 inclusive.

Z M 42517 F